IMPACT OF THE IMPLEMENTATION OF THE 2000/2001 IECC ON RESIDENTIAL ENERGY USE IN TEXAS: ANALYSIS OF RESIDENTIAL ENERGY SAVINGS

Mushtaq Ahmad
Research Engineer

Piljae Im,
Graduate Research Assistant

Jaya Mukhopadyay
Architect
Kirksey Architecture

Mini Malhotra
Graduate Research Assistant

Jeff Haberl
Professor/Assc. Director

Charles Culp
Assc. Professor/Assc. Director

Bahman Yazdani
Assc. Director

Energy Systems Laboratory
Texas A&M University

ABSTRACT

In September 2001, Texas adopted the 2000 International Residential Code (IECC 2000), including the 2001 Supplement as the state energy building code. This building code has substantially improved the energy efficiency of housing in Texas, resulting in reduced annual heating/cooling utility bills for residential customers. Since this time the Texas Legislature has required that the energy savings and emissions reductions from the implementation of the Texas Building Energy Standards (TBEPS) be tracked annually and cumulative savings reported to the Texas Commission on Environmental Quality (TCEQ). To accomplish this, code-compliant DOE-2 simulations were developed for code and pre-code conditions for each county in the non-attainment and affected counties, and used to calculate the savings per house, which were then multiplied by the housing starts in each county, and aggregated to state-wide totals. This paper outlines the analysis methods for accomplishing this task and reports the savings for 2005 for single-family and multi-family residential construction.

BACKGROUND:

In 2001, the Texas State Legislature formulated and passed the Texas Emissions Reduction plan in Senate Bill 5 to further reduce ozone levels by encouraging the reduction of emissions of NO_x by sources that are currently not regulated by the state, including area sources (e.g., residential emissions), on-road mobile sources (e.g., all types of motor vehicles), and non-road mobile sources (e.g., aircraft, locomotives, etc.)[1]. An important part of this legislation is the evaluation of the State's new energy efficiency programs, which includes reductions in energy use and demand that are associated with specific utility-based energy conservation measures, and implementation of the International Energy Conservation Code (IECC), published in 2000 as amended by the 2001 Supplement (IECC 2000; 2001). This paper provides a detailed discussion of the analysis methods and simulation tools employed to quantify the total savings achieved by the implementation of the 2000/2001 IECC in residential new construction in non-attainment and affected counties.

METHODOLOGY:

In order to quantify the energy savings achieved by the implementation of the 2000/2001 IECC, simulation models were created for both single-family and multi-family configuration. Figures 1 and 2 show the example of each simulation model. The simulation models were then modified to accommodate the different scenarios of envelope construction and HVAC equipment typically used in residences. The characteristics published by the National Association of Home Builders (NAHB 2004) for typical residential construction in East and West Texas for 1999, was used as the base case. Measured hourly weather data for nine locations in Texas was obtained from the National Oceanic

[1] In the 2003 Texas State legislative session, the emissions reductions legislation in Senate Bill 5 was modified by House bill 3235, and House bill 1365. In the 2005 Texas State Legislative sessions, the TERP was modified by House bills 965 and 2129. In general, this new legislation strengthens the previous legislation, and did not reduce the stringency of the building code or the reporting of the emissions reductions.

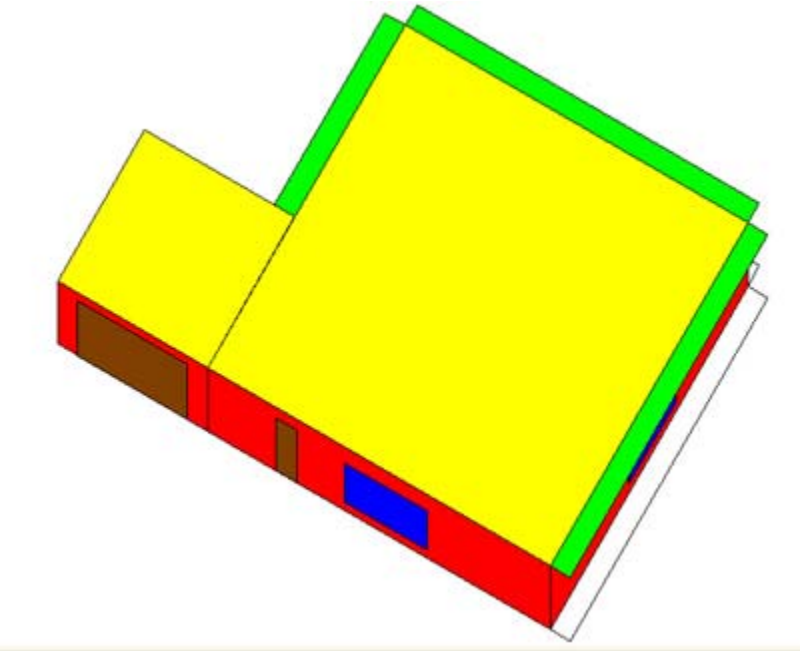

Figure 1: Prototype of a Single Family House (1 story with attached garage) (DrawBDL rendering).

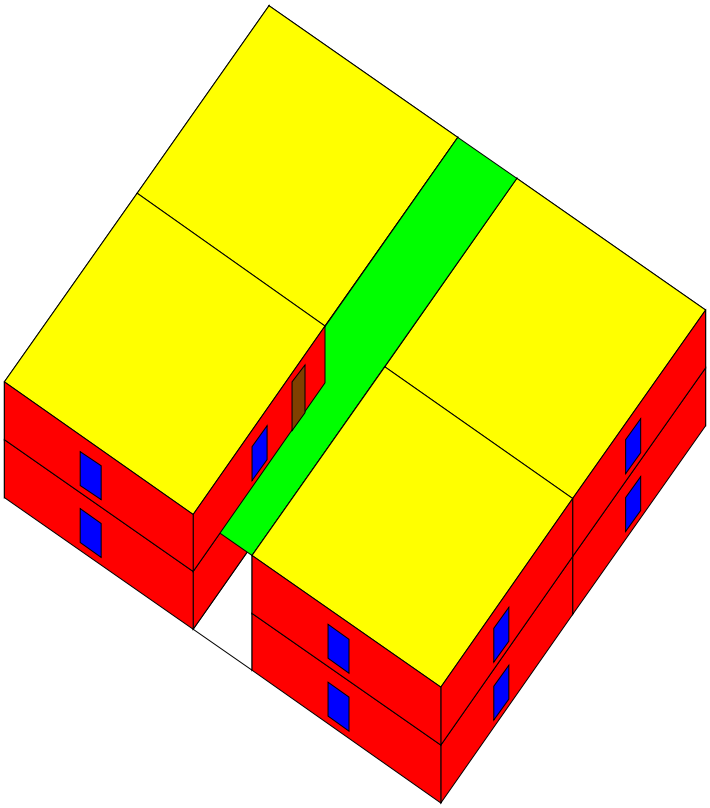

Figure 2: Prototype of Multifamily House (2 stories, 8 units) (DrawBDL rendering).

and Atmospheric Administration's (NOAA) National Weather Service for 1999.[2]

Overview:

For both single-family and multi-family house types, two simulation runs are performed: 1) a base-case (Pre-code) run based on the construction characteristics published by the National Association of Home Builders (NAHB 2004) for 1999, 2) A Code-compliant run based on the minimum construction requirement of the 2000/2001 IECC. The pre-code NAHB characteristics are different for counties situated in east or west Texas for single-family construction, the main difference being the window-to-wall area ratio and the glazing characteristics. However, for multi-family residential the NAHB characteristics are same for all of Texas. The typical characteristics of single and multi-family residences according to NAHB 1999 are provided in Tables 1 and 2, which include significant differences in the reported window-to-wall areas for the east and west Texas single-family residences.

The 2000/2001 IECC code characteristics for the single and multi-family residences are based on the minimum requirements according to climate zone and window-to-wall area ratio. Tables 502.2.4(1) to 502.2.4(9) of the IECC provide the prescriptive values for envelope insulation, glazing u-factor and minimum equipment efficiencies. Table 3 provides an example of the type of information available from the prescriptive tables from Chapter 5 of the 2000/2001 IECC along with the pre-code requirements from NAHB for Harris County. Figure 3 shows the Texas County map with the available weather stations.

In the case of single-family residences, 12 simulations were performed for both code and pre-code options (i.e. foundation type, system type and number of stories) for the 41 affected and non-attainment counties. The total number of simulations required for all counties for both code and pre-code options, using 9 weather stations was 984 runs.

In case of multifamily residences, 9 simulations were performed for both code and pre-code options (i.e. foundation type, system type and number of units/stories) for the 41 affected and non-attainment counties. The total number of simulations required for all counties for both code and pre-code options, using 9 weather stations was 738 runs.

In order to facilitate the analysis, a batch simulation tool, the Batch DOE-2 Input (BDI), was developed that uses a reduced set of input parameters incorporated in one row of an excel spreadsheet. Using the BDI, 984 simulations required only 984 rows in a spreadsheet. All the simulation runs were executed in one pass through the command line shown in Figure 4. Figure 5 shows an example of the spreadsheet used to generate the parametric include file for the DOE-2 simulation.

Single-Family Input File:

Table 4 shows all the parameters used by the BDI spreadsheet to generate a single-family simulation model. The parameters are divided into two major categories; LOADS and SYSTEMS, which corresponds to the DOE-2's BDL. The LOADS are then further divided into building, construction, space and shading parameters. Each division is a separate tab in the BDI spreadsheet (Figure 5). The building parameters (tabs: BLDG1 and BLDG2) are used to define the location, orientation and the basic dimensions and layout of the building.

The current simulation model has the provision of either one or two stories with a crawlspace or a slab-on-grade foundation type. The switch between quick (i.e., pre-calculated ASHRAE weighting factors) and thermal mass (i.e., DOE-2's custom weighting factors) mode is currently fixed at quick construction for the 2005 reporting year with the floor-weight equal to 11.5 lb/ft2, as required by Chapter 4 of the 2000/2001 IECC .

The construction parameters (tabs: CONS1 and CONS2) include the material properties and U-values for the different components, the glazing properties, and the window-to-wall area ratio. For both the code and pre-code run, the total window area is either 13.8% or 20.6% of exterior wall area depending on the location of county in either east or west Texas, respectively. This window-to-wall ratio is based on the NAHB data on the average number of windows in a household (NAHB, 2002). In order to derive the window-to-wall ratio from this information, a survey of available windows in Texas from

[2] In 2005 this was expanded to include 17 weather stations.

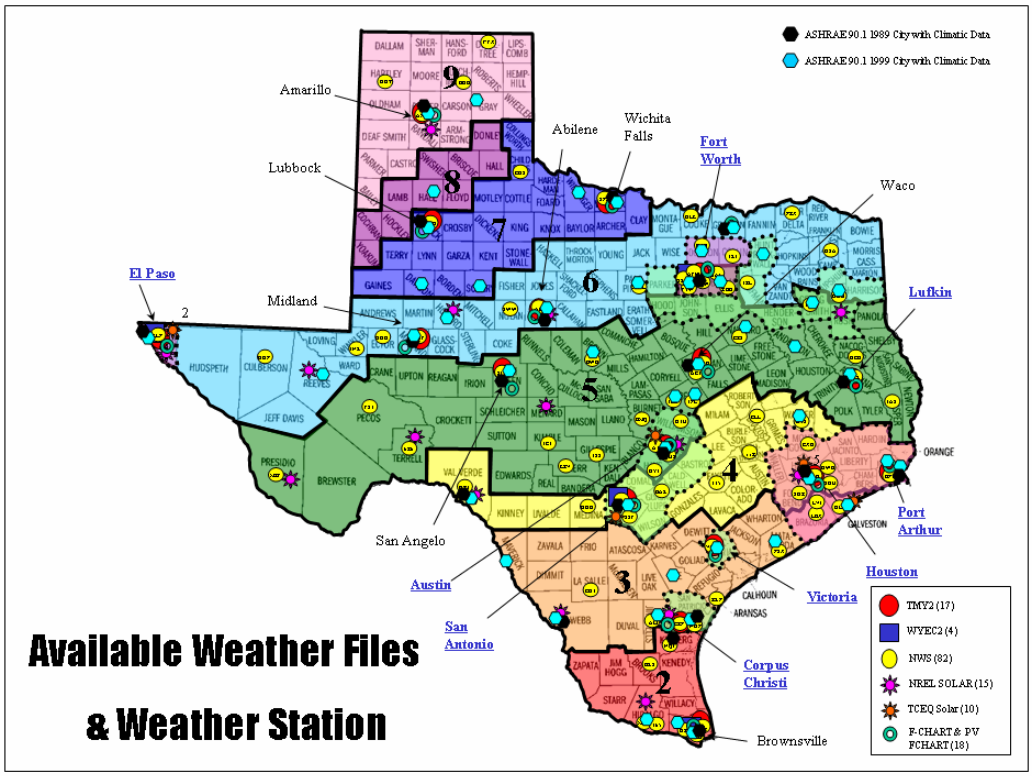

Figure 3: Available Weather Stations in Texas.

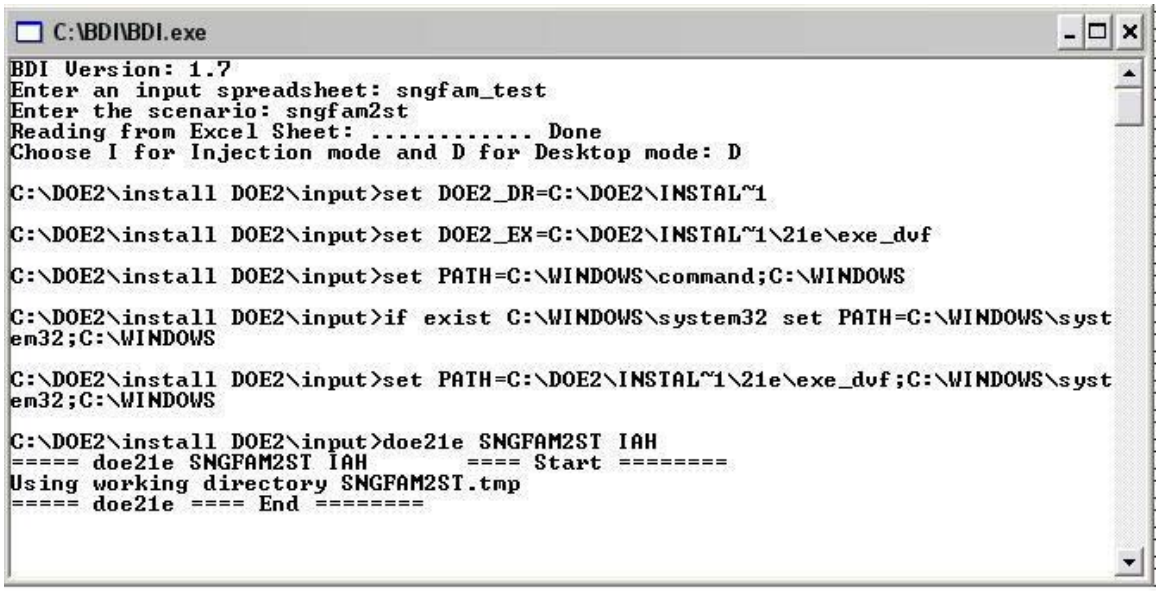

Figure 4: BDI command line for batch DOE-2 run.

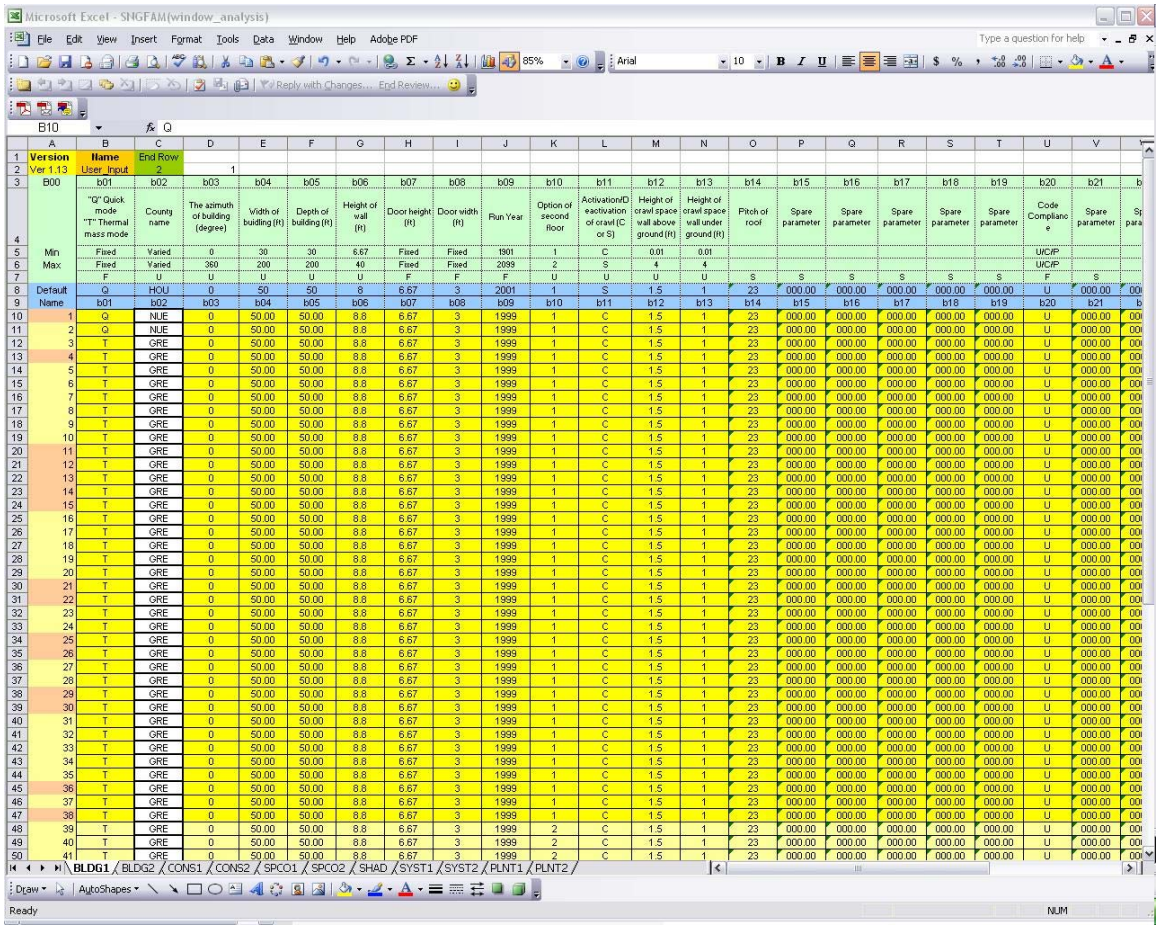

Figure 5:. Example of a BDI spreadsheet.

retailers (Lowe's and Home Depot) showed that the most common size of a window is 3' x 5'.

For simulating residential buildings, according to 2000/2001 IECC, internal heat gains were fixed at 3,000 Btu/hr for a single-family dwelling, which limits the user's ability to change the lighting, occupancy and equipment gains. The space parameters (tab: SPC01) are currently fixed at 2 occupants and 1 bedroom. The number of bedrooms is used to calculate the daily domestic hot water consumption which in turn is used to size the domestic hot water heater according to section 420.1.3.7 of the 2000/2001 IECC.

The system parameters (tabs: SYST1 and SYST2) include the type of systems, the system capacity and the efficiencies of the selected system. Three types of systems are currently being simulated for the code and pre-code runs; 1) gas heating, gas DHW and electric cooling 2) electric resistance heating, electric resistance heating, electric resistance DHW and electric cooling, and 3) electric heat pump heating, electric resistance DHW and electric cooling. For the pre-code configuration, two pilot lights are being assumed for the DHW and furnace while for the code run, the furnace pilot light has been removed. Currently, the heating and cooling system is auto-sized by DOE-2 according to the loads entered in DOE-2's LOADS sub-program. Since minimum system efficiencies required for the 2000/2001 IECC are lower than the average efficiencies of the installed systems (NAHB 2002), the installed system efficiencies were used, which yields no improvement in energy use. For the code and pre-code runs, the efficiency values are in Table 3. The Minimum efficiency requirements for the code runs are based on NAECA 1987.

Table 1: NAHB residential characteristics for East and West Texas (Single-Family).

Single Family Detached

	Required Data	NAHB (East Texas)	NAHB (West Texas)
Year		1999	1999
Envelope	Floor Area (ft^2)	2548.01	2426.43
	Wall height(ft)	8.8	9.2
	Wall R-value (hr. ft^2.degF/Btu)	13.99 (Combined R)	14.18 (Combined R)
	Roof/Ceiling R-value (hr. ft^2.degF/Btu)	27.08	26.75
	Window area (%)[1]	13.8% (16.4 units of windows)	20.6% (24.9 units of windows)
	Glazing U-factor [2] (Btu/hr. ft^2.degF)	1.11	0.87
	SHGC [3]	0.714	0.66
Building Mechanical Systems and Equipment	AFUE (Gas-fired or oil-fired furnace < 225,000 Btu/hr)	80%	80%
	SEER (Air-cooled air conditioners and heat pumps cooling mode < 65,000 Btu/hr cooling capacity)	12	12

Notes:

1. Window area: Assume average window size is 3x5.

Total window area for east Texas house: 3x5x16.4 =246 ft2
Total wall area for east Texas house: 50.5 (length of house)x4x8.8(height of house) = 1777.6 ft2
Total window area for west Texas house: 3x5x24.9 =373.5 ft2
Total wall area for wast Texas house: 49.3 (length of house)x4x9.2(height of house) = 1814.2 ft2

2.Calculation of U-factors

	Aluminum Without Thermal Break	SHGC
Single Glazing (1/8 in glass)	1.27	0.75
Double Glazing (1/4 in air space)	0.87	0.66

Source: 2001 ASHRAE HANDBOOK FUNDAMENTALS

U-factor for east Texas: 60% of single pane and 40%of double pane glass
: (0.6 X 1.27) +(0.4 X 0.87) = 1.11
U-factor for west Texas: 100% of double pane glass
: 0.87

3.Calculation of SHGC

SHGC for east Texas: 60% of single pane and 40%of double pane glass
: (0.6 X 0.75) +(0.4 X 0.66) = 0.714
SHGC for west Texas: 100% of double pane glass
0.66

Table 2: NAHB residential characteristics for Texas (Multi-family).

	Required Data	NAHB (West South Central)
Year		1999
Envelope	Floor Area (ft^2)	1009.3402
	Wall height(ft)	8.441 (1st) 8.342 (2nd)
	Wall R-value (hr. ft^2.degF/Btu)	21.414 (Combined R)
	Roof/Ceiling R-value (hr. ft^2.degF/Btu)	36.083
	Window area (%)[1]	7.5% (5.326 units)
	Glazing U-factor [2] (Btu/hr. ft^2.degF)	0.7535
	SHGC [3]	0.605
Building Mechanical Systems and Equipment	AFUE (Gas-fired or oil-fired furnace < 225,000 Btu/h)	80%
	SEER (Air-cooled air conditioners and heat pumps cooling mode < 65,000 Btu/h cooling capacity)	12

Notes:

1. Window area: Assume average window size is 3x5.

Total window area for West South Central house: 3x5x5.326 = 79.89 ft2
Total wall area for West South Central house: 31.76 (length of house)x4x8.4(height of house) = 1067.14 ft2

2.Calculation of U-factors

	Aluminum Without Thermal Break	Wood/ Vinyl	SHGC
Double Glazing (1/4 in air space)	0.87	0.55	0.66(Aluminum) 0.55(Other frames)

Source: 2001 ASHRAE HANDBOOK FUNDAMENTALS

U-factor : 100% double pane, 50% of aluminum and 50%of vinyl frame
: (0.5 X 0.87) +(0.5 X 0.55) = 0.7535

3.Calculation of SHGC

SHGC : 100% double pane, 50% of aluminum and 50%of vinyl frame
: (0.5 X 0.66) +(0.5 X 0.55) = 0.605

Table 3: Code and pre-code building characteristics for Harris County.

Harris County	Required Data	NAHB	IECC
Year		1999	2000/2001
Envelope Requirements	Wall R-value (hr. ft^2.degF/Btu)	14	13
	Roof/Ceiling R-value (hr. ft^2.degF/Btu)	27	26
	Glazing U-factor [2] (Btu/hr. ft^2.degF)	1.11	0.75
	SHGC [3]	0.71	0.4
Minimum HVAC Efficiencies	Heating (AFUE)	80%	78%
	Cooling (SEER)	11	10

Table 4: Single-Family input parameters.

PARAMETER NO:	DESCRIPTION	DEFAULT	STATUS	COMMENT
LOADS				
b01	Quick or thermal mode (Q or T)	Quick (Q)	Fixed	Q simulates the building as massless, T will include thermal mass
b02	Location (county name)	Bastrop (BAS)	User Defined	41 counties linked to 9 TRY packed weather files according to climate zone
b03	Azimuth of building (degree)	0	User Defined	Orientation of the building
b04	Width of building (ft)	50	User Defined	
b05	Depth of building (ft)	50	User Defined	
b06	Height of wall (ft)	8	User Defined	
b07	Door height (ft)	6.67	Fixed	Value from survey of manufactured doors
b08	Door width (ft)	3	Fixed	Value from survey of manufactured doors
b09	Run year	2000	User Defined	
b10	Option of second floor (1 or 2)	one floor (1)	User Defined	Controls activation/deactivation of one and two story portions of the BDL input
b11	Activation/ Deactivation of crawl (C or S)	Slab (S)	User Defined	Controls activation/deactivation of crawl space and slab on grade floor types for the residence
b12	Height of crawl space wall above ground(ft)	1.5	User Defined	
b13	Height of crawl space walll under ground(ft)	1	User Defined	
c01	Roof outside emissivity	0.89	User Defined	c01 and c02 are used to define "Roof color"
c02	Roof absorptance	0.45	User Defined	
c03	Roof roughness	1	Fixed	This is used to calculate the outside film coefficient for heat transfer calculations, DOE-2 allows values from 1 to 6 increasing in smoothness
c04	Roof R-value (Hr-sq.ft-F/Btu)	R-26	User Defined	
c05	Wall absorptance	0.57	User Defined	c05 and c07 are used to define "wall color"
c06	Wall roughness	2	Fixed	This is used to calculate the outside film coefficient for heat transfer calculations, DOE-2 allows values from 1 to 6 increasing in smoothness
c07	Wall outside emissivity	0.9	User Defined	c05 and c07 are used to define "wall color"
c08	Wall R-value (Hr-sq.ft-F/Btu)	R-13	User Defined	
c09	Ground reflectance	0.24	Fixed	This defines the fraction of sunlight reflected from the ground
c10	Window option (S or D)	Same (S)	User Defined	Controls the input of same or different windows on individual orientation of the house
c11	U-Factor of glazing (Btu/hr-sq.ft-F)	0.75	User Defined	
c12	Solar Heat Gain Coefficient(SHGC)	0.4	User Defined	
c13	Number of panes of glazing	2	Fixed	
c14	Frame absorptance of glazing	0.7	Fixed	
c15	Frame type - A,B,C,D,E	Aluminium w/o thermal break (A)	User Defined	Allows user to select from 5 different frame types
c16	Void			
c17	Floor weight (lb/sq-ft)	11.5	Fixed	Value from IECC 2000
c18	Void			
c19	R-value of concrete slab (hr-sq.ft-F/Btu)	0.44	Fixed	
c20	Air film resistance (hr-sq.ft-F/Btu)	0.77	Fixed	
c21	Percentage of window area (%) for whole area or front side wall	15	User Defined	
c22	Percentage of window area (%) for back side wall	15	User Defined	
c23	Percentage of window area (%) for right side wall	15	User Defined	
c24	Percentage of window area (%) for left side wall	15	User Defined	
c25	Percentage of window area (%) for 2nd floor left side wall	15	User Defined	
c26	Floor R-Value (hr-sq.ft-F/Btu)	11	User Defined	
c27	Crawl space wall R-value (hr-sq.ft-F/Btu)	R-5 (F)	User Defined	Allows user to select from 13 different insulations
c28	Slab perimeter R-value and depth	R-0 (A)	User Defined	Allows user to select from 11 different insulation R-values and depths
sp01	Number of people	2	User Defined	
sp02	Number of bedroom	1	User Defined	
s01	Front eave shade (ft)	0	User Defined	
s02	Back eave shade (ft)	0	User Defined	
s03	Left eave shade (ft)	0	User Defined	
s04	Right eave shade (ft)	0	User Defined	
SYSTEM				
sy01	Mode of system: 1, 2, 3	Gas/Electric (1)	User Defined	Allows user to select all-electric, gas/electric or heatpump for HVAC
sy02	Cooling Capacity of cooling system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy03	Heating Capacity of heating system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy04	Seasonal Energy Efficiency Ratio (SEER)	10	User Defined	
sy05	ANNUAL FUEL UTILIZATION EFFICIENCY (AFUE)	0.8	User Defined	
sy06	HEATING SEASONAL PERFORMANCE FACTOR (HSPF)	6.8	User Defined	
sy07	The number of pilot lights of DHW	0	User Defined	
sy08	The number of pilot lights of Furnace	0	User Defined	
sy09	The number of pilot lights of others	0	User Defined	
sy10	Switch for Energy Factor for Domestic Hot Water consumption	Autosized (A)	User Defined	Allows user to input a DHW or let DOE-2 calculate the size and efficiency of the DHW
sy11	Energy Factor (%) for Domestic Hot Water	54	User Defined	Only applicable if the user chooses sy10 = S (EF is user defined)

Multi-family Input File:

Table 5 describes the parameters that are required to generate the multi-family simulation model through the BDI. The current multi-family model can be simulated with one, two or three stories, from 2 to 12 units in contrast to the single family simulation. The multi-family version has only a fixed slab on grade. Conversely, in a similar fashion as the single-family simulations, pre-calculated ASHRAE weighting factors were used for the 2005 reporting.

The construction parameters include the material properties and U-values for the different components including the glazing properties and the window-to-wall area ratio. The window-to-wall ratio uses the multifamily characteristics from the NAHB. The single family assumptions based on the survery of local retailers for the window size were used to calculate the window to wall ratio.

For simulating multi-family residential buildings, according to 2000/2001 IECC, the internal heat gains were fixed at 1,500 Btu/hr. The space parameters were fixed at 2 occupants and 1 bedroom per living unit. In a similar fashion as the single-family simulation, the number of bedrooms is used to calculate the daily domestic hot water consumption, which in turn is used to size the domestic hot water heater according to Section 420.1.3.7 of 2000/2001 IECC. The relation in Section 420.1.3.7 has a slight discrepancy when calculating DHW consumption for multifamily homes. The relation does not take into account the total number of units. So, if there are 10 units and each unit has 1 bedroom then the DHW consumption will be calculated for 1 bedroom rather than 10 bedrooms. The current simulation does not take this into account. The DHW consumption is still being calculated for one bedroom configuration irrespective of the number of units.

The multi-family system parameters include the type of systems, the system capacity and the efficiencies of the system selected. In a similar fashion as the single-family residential, the pre-code and code simulations were run for: 1) gas heating, gas DHW and electric cooling 2) electric resistance heating, electric resistance DHW and electric cooling, and 3) electric heat pump heating, electric resistance DHW and electric cooling. Multi-family pilot lights were treated in a similar fashion as the single-family residential, heating and cooling systems are auto-sized by DOE-2. Code and pre-code efficiencies are shown in Table 3.

Code and Pre-code Comparison:

As mentioned earlier, 984 single family and 738 multifamily simulations were run to analyze the impact on implementing the 2000/2001 IECC in new construction. The next step after the simulations was to extract the relevant data from the DOE-2 output files.

The annual and Ozone Season Day (OSD), which is defined as the average daily consumption between the period of July 15th and September 15th (in kWh or therms, depending on the type of system) was extracted from the simulation output by creating customized data extraction routines using an AWK script.

Real estate data obtained from the Real Estate Center, Texas A&M University (RECS, 2006) was used to determine the total number of new single and multifamily houses built in each of the 41 affected and non-attainment counties. Data was also available for determining what percentage of new construction had slab-on-grade, layout of the house, or type of HVAC system.

Tables 6 and 7 show the information for Harris County. For single-family household, the total number of building permits issued for this county were 28,020. Of these 93.6% homes were slab-on-grade, 77.1% had electric cooling, natural gas heating and domestic hot water. Of the slab-on-grade houses, more than 40% were two-story construction while for the crawlspace houses, more than 39% were two-story.

For multi-family household, a total of 8,375 permits were issued for the year 2004. 100% of these were slab-on-grade, more than 66% had all-electric HVAC systems, 89% were two-story new construction. The energy consumption obtained from all the different simulation scenarios was then adjusted according to the above mentioned data to allow for a more realistic comparison. This procedure was then repeated for all the 41 counties. The final savings numbers from each county was then increased by 7% to account for the distribution and transmission loss.

Table 5. Multi-family input parameters.

PARAMETER NO:	DESCRIPTION	DEFAULT	STATUS	COMMENT
LOADS				
b01	Quick or thermal mode (Q or T)	Quick (Q)	Fixed	Q simulates the building as massless, T will include thermal mass
b02	Location	Bastrop (BAS)	User Defined	41 counties linked to 9 TRY packed weather files according to climate zone
b03	Azimuth of building (degree)	0	User Defined	Orientation of the building
b04	Width of unit (ft)	30	User Defined	
b05	Depth of unit (ft)	30	User Defined	
b06	Height of wall (ft)	8	User Defined	
b07	Door height (ft)	6.67	Fixed	Value from survey of manufactured doors
b08	Door width (ft)	3	Fixed	Value from survey of manufactured doors
b09	Run Period	2000	User Defined	
b10	Unit Configuration	1 floor 2 units (A)	User Defined	User can choose from 6 different configurations from 1 floor 2 units to 3 floors 12 units
b11	Activation/ Deactivation of crawl (C or S)	Slab (S)	Fixed	In Multifamily the crawl space is always deactivated
b12	Height of crawl space wall above ground(ft)	1.5	Fixed	Crawl space is deactivated
b13	Height of crawl space waill under ground(ft)	1	Fixed	Crawl space is deactivated
c01	Roof outside emissivity	0.89	User Defined	c01 and c02 are used to define "Roof color"
c02	Roof absorptance	0.45	User Defined	
c03	Roof roughness	1	Fixed	This is used to calculate the outside film coefficient for heat transfer calculations, DOE-2 allows values from 1 to 6 increasing in smoothness
c04	Roof R-value (Hr-sq.ft-F/Btu)	R-19	User Defined	
c05	Wall absorptance	0.57	User Defined	c05 and c07 are used to define "wall color"
c06	Wall roughness	2	Fixed	This is used to calculate the outside film
c07	Wall outside emissivity	0.9	User Defined	c05 and c07 are used to define "wall color"
c08	Wall R-value (Hr-sq.ft-F/Btu)	R-11	User Defined	
c09	Ground reflectance	0.24	Fixed	This defines the fraction of sunlight reflected from the ground
c10	Window option (S or D)	Same (S)	User Defined	Controls the input of same or different windows on individual orientation of the house
c11	U-Factor of glazing (Btu/hr-sq.ft-F)	0.85	User Defined	
c12	Solar Heat Gain Coefficient(SHGC)	0.4	User Defined	
c13	Number of pane of glazing	2	Fixed	
c14	Frame absorptance of glazing	0.7	Fixed	
c15	Frame type - A,B,C,D,E	Aluminum w/o thermal break (A)	User Defined	Allows user to select from 5 different frame types
c16	VOID			
c17	Floor weight (lb/sq-ft)	11.5	Fixed	Value from IECC 2000
c18	VOID			
c19	R-value of concrete slab (hr-sq.ft-F/Btu)	0.44	Fixed	
c20	Air film resistance (hr-sq.ft-F/Btu)	0.77	Fixed	
c21	Percentage of window area (%) for front side wall	20	User Defined	
c22	Percentage of window area (%) for back side wall	20	User Defined	
c23	Percentage of window area (%) for right side wall	20	User Defined	
c24	Percentage of window area (%) for left side wall	20	User Defined	
c25	Floor R-Value (hr-sq.ft-F/Btu)	11	User Defined	
c26	Crawl space wall R-value (hr-sq.ft-F/Btu)	R-5 (F)	Fixed	Crawl space is deactivated
c27	Slab perimeter R-value and depth	R-0 (A)	User Defined	Allows user to select from 11 different insulation R-values and depths
sp01	Number of people	2	User Defined	
sp02	Number of bedroom	1	User Defined	
s01	Front eave shade (ft)	0	User Defined	
s02	Back eave shade (ft)	0	User Defined	
s03	Left eave shade (ft)	0	User Defined	
s04	Right eave shade (ft)	0	User Defined	
SYSTEM				
sy01	Mode of system: 1, 2, 3	Gas/electric (1)	User Defined	Allows user to select all-electric, gas/electric or heatpump for HVAC
sy02	Cooling Capacity of cooling system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy03	Heating Capacity of heating system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy04	Seasonal Energy Efficiency Ratio (SEER)	10	User Defined	
sy05	ANNUAL FUEL UTILIZATION EFFICIENCY (AFUE)	0.8	User Defined	
sy06	HEATING SEASONAL PERFORMANCE FACTOR (HSPF)	6.8	User Defined	
sy07	The number of pilot lights of DHW	0	User Defined	
sy08	The number of pilot lights of Furnace	0	User Defined	
sy09	The number of pilot lights of others	0	User Defined	
sy10	Switch for Energy Factor for Domestic Hot Water consumption	Autosized (A)	User Defined	Allows user to input a DHW or let DOE-2 calculate the size and efficiency of the DHW
sy11	Energy Factor (%) for Domestic Hot Water	54	User Defined	Only applicable if the user chooses sy10 = S (EF is user defined)

RESULTS:

Figure 6, Table 8 and Table 9 show the total energy savings for the all the different counties by the implementation of the 2000/2001 IECC. In 2004 263,655 MWh/year and 1,299 MWh/OSD electricity savings were achieved for new single-family construction in the year 2004. The natural gas savings in 2004 were 736,929 MMBtu/year and 1,238 MMBtu/OSD. The total number of single-family residential permits issued in 2004 was 126,804. The largest number of permits was issued for Harris County, amounting to 28,020. The annual energy savings for Harris County are 49,540 MWh/year and 98,645 MMBtu/year. Of these, almost 21,000 MWh/year and 55,600 MMBtu/year savings were achieved for one-story slab-on-grade construction with electric cooling and natural gas heating. This high percentage is due to the fact that this is the most common construction, and removal of the furnace pilot light has a huge impact on the gas savings. The 2000/2001 IECC does not mandate the installation of a furnace with electronic ignition, but the industry is manufacturing all new furnaces with pilot lights since 1995, this shows that all new furnaces installed will have electronic ignition.

For multifamily, the electricity savings achieved by the implementation of the 2000/2001 IECC were 10,451 MWh/year and 44 MWh/OSD. The natural gas savings are 27,528 MMBtu/year and 81.3 MMBtu/OSD. The total number of permits issued for 2004 were 29,974. Of these Harris County has the largest number of permits, 8,375. The annual energy savings for Harris County are 2,859 MWh/year and 6,941 MMBtu/year. The maximum electricity savings were achieved from two-story slab-on-grade all electric construction since it is the most common type of construction. The maximum gas savings were achieved by the removal of the pilot light from the two-story slab-on-grade electric cooling, gas heating construction. Figures 7-14 show the annual and OSD energy savings for Harris County for both single and multifamily construction.

SUMMARY:

This paper explains in detail the residential simulation models that are used to report the annual energy savings achieved by the implementation of the 2000/2001 IECC on the new residential construction for the 41 affected and non-attainment counties of Texas. To accomplish this, the DOE-2.1e simulation program was used to create pre-configured, single family and multifamily simulation models. These models were then used to determine the fuel-neutral, annual and Ozone Season Day energy savings attained by constructing code-complaint residences. These values were then processed through US EPA's eGRID to calculate the annual and OSD NOx emissions reductions for the counties that contain the power plants that supplied the electricity to the households.

This same methodology has been used to create a web-based simulation tool that can be utilized to check how much energy can be savings if the building construction is at or above the 2000/2001 IECC. Upgraded simulation models are being created to take into account the effect of thermal mass, duct loss and improved equipment sizing.

Preliminary verifications of the accuracy of the energy calculations in the calculator can be found in Im (2003). Ongoing verification efforts include calibrated simulations with an instrumented Habitat for Humanity house in Bryan, Texas, (Kim, 2006) and verification of whole-building reductions using utility bill comparisons (Baltazar Cervantes, 2006).

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Table 6: Number of permits and house types for single family construction (Harris County).

County Name	Harris
Division (East or West Texas)	East Texas
Number of new building permits for SFD	28,020

		Fuel Option			Total
		1	2	3	
		Elec. cooling, NG heating and NG water heating	All electricity	Elec. cooling, Heat pump heating and elec. water heating	
		77.1%	18.9%	4.0%	
Slab-on-grade (93.6%)	1-Story (59.8%)	43.16%	10.58%	2.24%	55.97%
	2-Story (40.2%)	29.01%	7.11%	1.51%	37.63%
Crawl spaces (6.4%)	1-Story (59.8%)	2.95%	0.72%	0.15%	3.83%
	2-Story (39.2%)	1.98%	0.49%	0.10%	2.57%
Total		77.10%	18.90%	4.00%	100.00%

Number of Houses for each simulation

		Fuel Option			Total
		1	2	3	
		Elec. cooling, NG heating and NG water heating	All electricity	Elec. cooling, Heat pump heating and elec. water heating	
		77.1%	18.9%	4.0%	
Slab-on-grade (93.6%)	1-Story (59.8%)	12,092	2,964	627	15,684
	2-Story (40.2%)	8,129	1,993	422	10,543
Crawl spaces (6.4%)	1-Story (59.8%)	827	203	43	1,072
	2-Story (39.2%)	556	136	29	721
Total		21,603	5,296	1,121	28,020

Table 7: Number of permits and house types for multifamily construction (Harris County).

County Name	Harris
NAHB Division	West South Central
Number of new building permits for MF	8,375

		Fuel Option			Total
		1	2	3	
		Elec. cooling, NG heating and NG water heating	All electricity	Elec. cooling, Heat pump heating and elec. water heating	
		19.5%	66.4%	14.1%	
Slab-on-grade (100%)	1-Story (2.6%)	0.51%	1.73%	0.37%	2.60%
	2-Story (89.1%)	17.37%	59.16%	12.56%	89.10%
	3-Story (8.3%)	1.62%	5.51%	1.17%	8.30%
Total		19.50%	66.40%	14.10%	100.00%

Number of Houses for each simulation

		Fuel Option			Total
		1	2	3	
		Elec. cooling, NG heating and NG water heating	All electricity	Elec. cooling, Heat pump heating and elec. water heating	
		19.5%	66.4%	14.1%	
Slab-on-grade (100%)	1-Story (2.6%)	42	145	31	218
	2-Story (89.1%)	1,455	4,955	1,052	7,462
	3-Story (8.3%)	136	462	98	695
Total		1,633	5,561	1,181	8,375

Table 8: Annual and OSD energy savings from single family new construction (For 41 affected and non-attainment counties).

	County	Climate Zone	Total Savings (MWh) Precode-Code-compliant w/ 7% T&D Loss	Total OSD Savings (MWh/day) Precode-Code-compliant w/ 7% T&D Loss	Total Annual Savings (MMBtu/yr) Precode-Code-compliant	Total OSD Savings (MMBtu/day) Precode-Code-compliant
Affected County	Bastrop	4	666.69	3.11	1,307.97	2.59
	Bexar	4	18,207.73	88.29	49,247.41	90.70
	Caldwell	4	237.08	1.12	522.12	1.04
	Comal	4	3,220.05	15.57	8,707.48	16.04
	Ellis	5	4,092.90	21.69	12,446.32	18.15
	Gregg	6	464.89	2.40	1,527.42	2.76
	Guadalupe	4	2,638.20	12.78	7,140.24	13.15
	Harrison	6	68.60	0.35	225.65	0.41
	Hays	5	4,713.70	22.75	10,711.09	19.78
	Henderson	6	213.31	1.11	640.78	1.29
	Hood	5	210.05	1.11	640.31	0.93
	Hunt	5	432.64	2.49	1,804.54	1.93
	Johnson	5	2,081.99	11.03	6,313.28	9.21
	Kaufman	6	1,774.18	10.25	7,418.83	7.96
	Nueces	3	2,787.69	10.77	5,309.61	13.40
	Parker	6	807.34	4.66	3,370.47	3.60
	Rockwall	6	3,608.00	20.82	15,097.71	16.13
	Rusk	5	19.82	0.10	60.34	0.12
	San Patricio	3	582.06	2.25	1,103.72	2.78
	Smith	5	935.46	4.84	2,830.88	5.63
	Travis	5	18,717.70	90.17	42,396.81	78.28
	Upshur	6	14.10	0.07	46.13	0.08
	Victoria	3	207.36	0.99	486.11	1.28
	Williamson	5	10,187.52	49.01	23,004.79	42.48
	Wilson	4	82.69	0.40	224.71	0.41
Nonattain-ment County	Brazoria	3	5,785.00	25.32	11,582.06	30.42
	Chambers	4	1,053.38	4.56	1,989.71	5.28
	Collin	5	25,313.19	145.68	104,597.82	111.81
	Dallas	5	22,916.90	121.38	69,466.84	101.38
	Denton	6	14,684.76	84.62	60,998.87	65.20
	El Paso	6	8,379.49	33.78	35,224.41	34.38
	Fort Bend	4	6,819.56	29.83	13,477.97	35.69
	Galveston	3	5,274.22	23.06	10,544.02	27.71
	Hardin	4	213.85	0.93	406.03	1.06
	Harris	4	49,541.43	216.56	98,645.54	259.24
	Jefferson	4	1,308.30	5.67	2,460.44	6.58
	Liberty	4	490.83	2.12	916.97	2.43
	Montgomery	4	10,751.30	46.91	21,301.35	55.72
	Orange	4	462.74	2.01	875.14	2.32
	Tarrant	5	33,606.87	177.90	101,694.70	148.40
	Waller	4	82.08	0.36	162.60	0.43
	TOTAL		263,655.66	1,298.81	736,929.20	1,238.19

Table 9: Annual and OSD energy savings from Multifamily New construction (For 41 affected and non-attainment counties).

	County	Climate Zone	Total Savings (MWh) Precode-Code-compliant w/ 7% T&D Loss	Total OSD Savings (MWh/day) Precode-Code-compliant w/ 7% T&D Loss	Total Annual Savings (MMBtu/yr) Precode-Code-compliant	Total OSD Savings (MMBtu/day) Precode-Code-compliant
Affected County	Bastrop	4	20.95	0.08	51.37	0.15
	Bexar	4	1,206.34	5.35	3,508.89	10.14
	Caldwell	4	0.00	0.00	0.00	0.00
	Comal	4	69.88	0.31	203.26	0.59
	Ellis	5	24.43	0.14	78.60	0.24
	Gregg	6	26.26	0.12	80.75	0.22
	Guadalupe	4	362.76	1.61	1,055.18	3.05
	Harrison	6	0.00	0.00	0.00	0.00
	Hays	5	209.00	0.85	518.04	3.91
	Henderson	6	1.41	0.01	4.68	0.01
	Hood	5	2.86	0.02	9.30	0.03
	Hunt	5	79.32	0.40	223.46	0.60
	Johnson	5	0.00	0.00	0.00	0.00
	Kaufman	6	3.10	0.02	8.73	0.02
	Nueces	3	333.64	1.10	757.41	2.12
	Parker	6	21.36	0.11	60.21	0.16
	Rockwall	6	0.00	0.00	0.00	0.00
	Rusk	5	17.81	0.09	60.39	0.18
	San Patricio	3	65.40	0.22	148.48	0.42
	Smith	5	27.18	0.14	92.18	0.27
	Travis	5	981.06	4.00	2,431.75	6.79
	Upshur	6	0.00	0.00	0.00	0.00
	Victoria	3	73.99	0.31	0.00	0.00
	Williamson	5	42.27	0.17	104.78	0.29
	Wilson	4	1.11	0.00	3.24	0.01
Nonattain-ment County	Brazoria	3	368.33	1.37	894.22	2.52
	Chambers	4	0.00	0.00	0.00	0.00
	Collin	5	242.17	1.38	779.03	2.37
	Dallas	5	778.74	4.45	2,505.07	7.61
	Denton	6	304.98	1.55	859.56	2.30
	El Paso	6	185.83	0.73	464.53	1.25
	Fort Bend	4	100.36	0.37	243.65	0.69
	Galveston	3	1,022.39	3.80	2,482.11	7.01
	Hardin	4	0.00	0.00	0.00	0.00
	Harris	4	2,858.94	10.62	6,940.78	19.60
	Jefferson	4	17.44	0.07	39.31	0.11
	Liberty	4	0.00	0.00	0.00	0.00
	Montgomery	4	325.66	1.21	790.63	2.23
	Orange	4	0.00	0.00	0.00	0.00
	Tarrant	5	618.73	3.54	1,990.34	6.04
	Waller	4	57.01	0.21	138.40	0.39
	TOTAL		10,450.73	44.35	27,528.33	81.32

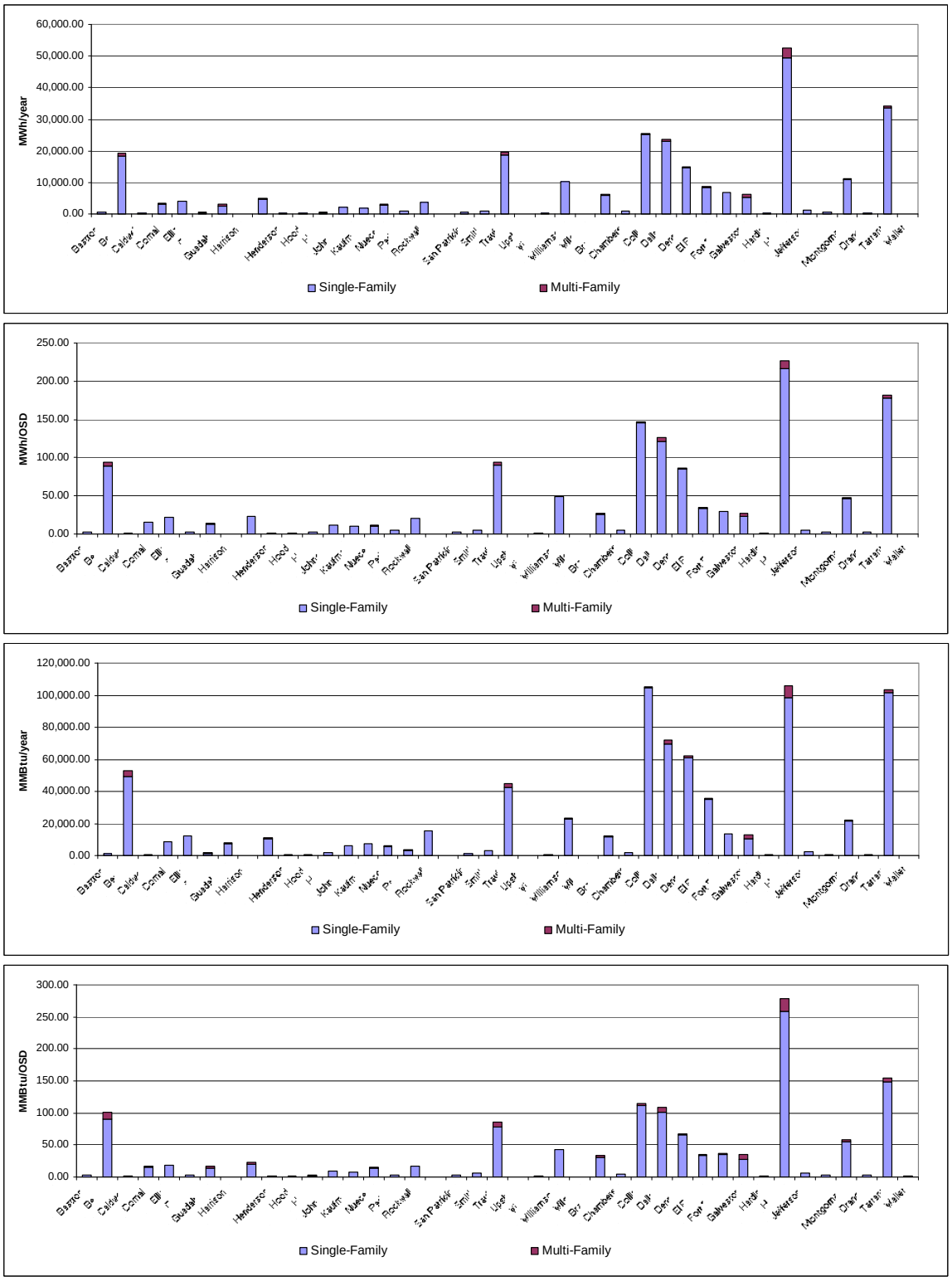

Figure 6: Annual and OSD MWh and MMBtu savings for the 41 non-attainment and affected counties (single-family and multi-family).

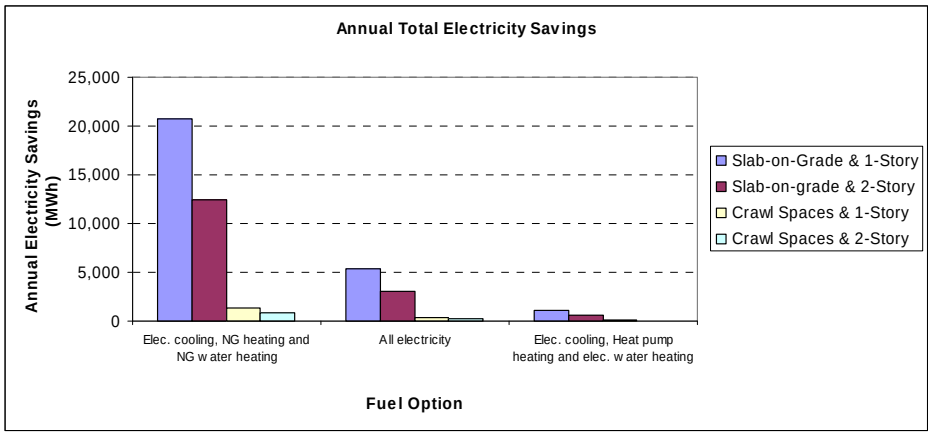

Figure 7: Annual electricity savings from single family new construction (Harris County).

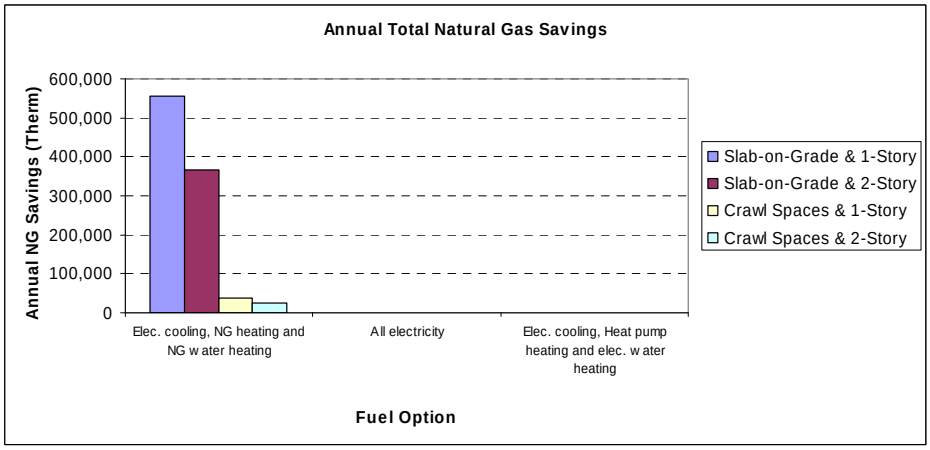

Figure 8: Annual gas savings from single family new construction (Harris County).

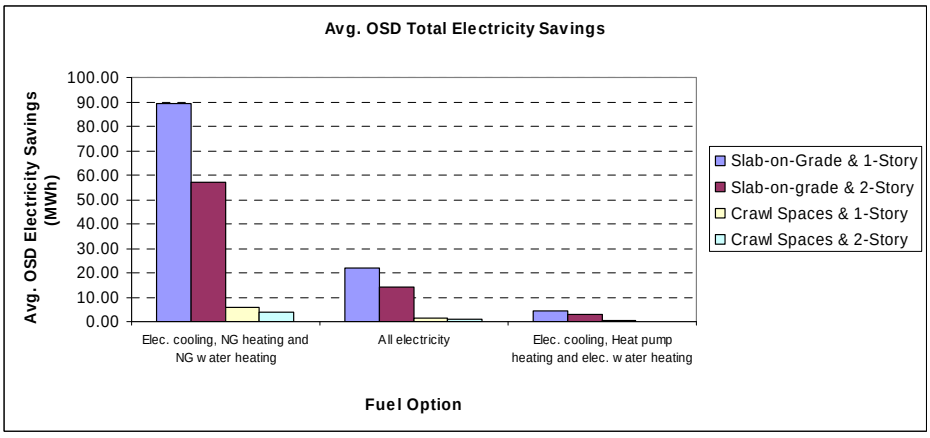

Figure 9: OSD electricity savings from single family new construction (Harris County).

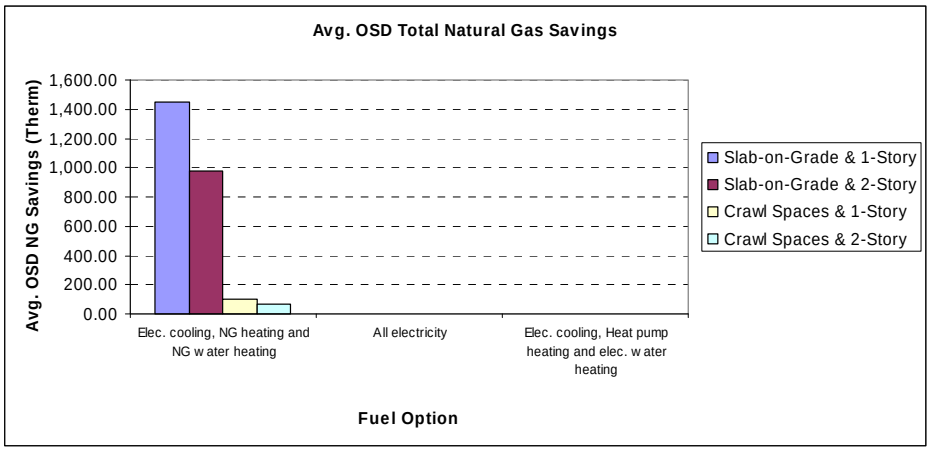

Figure 10: OSD gas savings from single family new construction (Harris County).

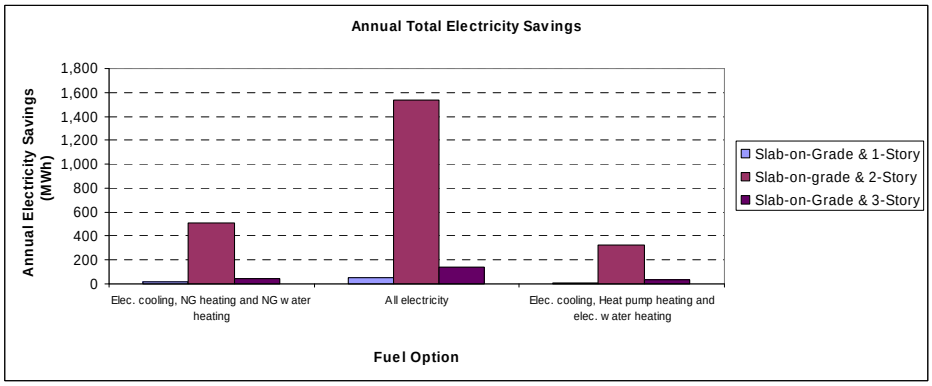

Figure 11: Annual electricity savings from multifamily new construction (Harris County).

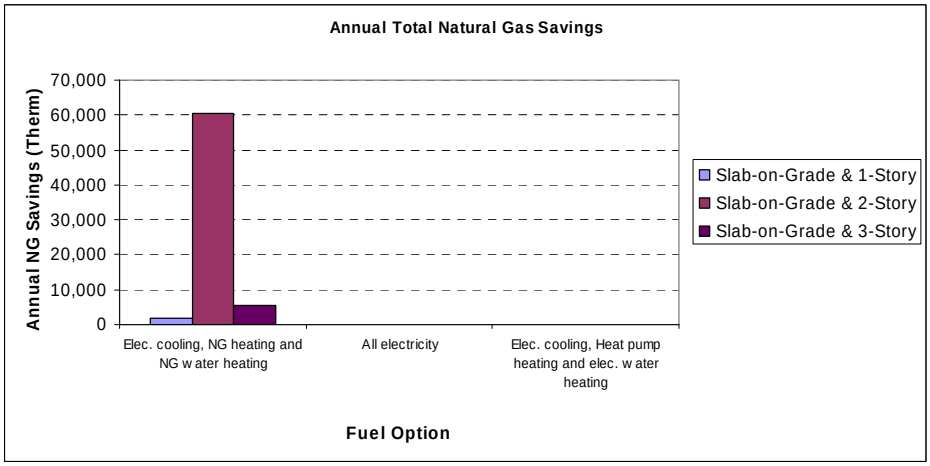

Figure 12: Annual gas savings from multifamily new construction (Harris County).

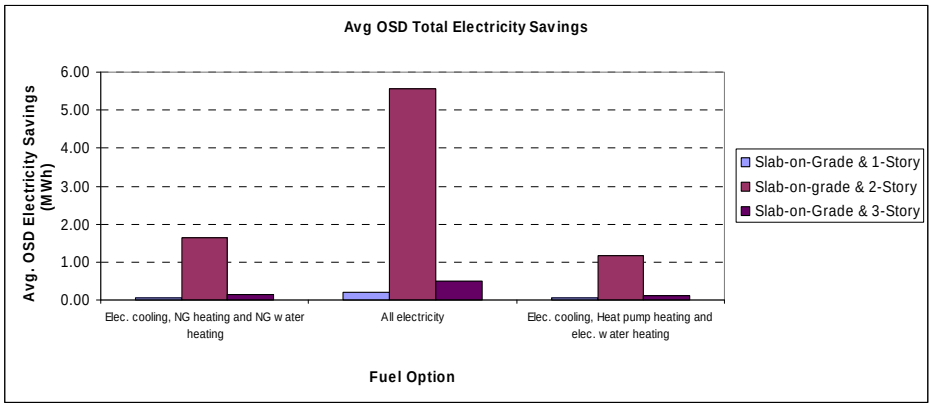

Figure 13: OSD electricity savings from multifamily new construction (Harris County).

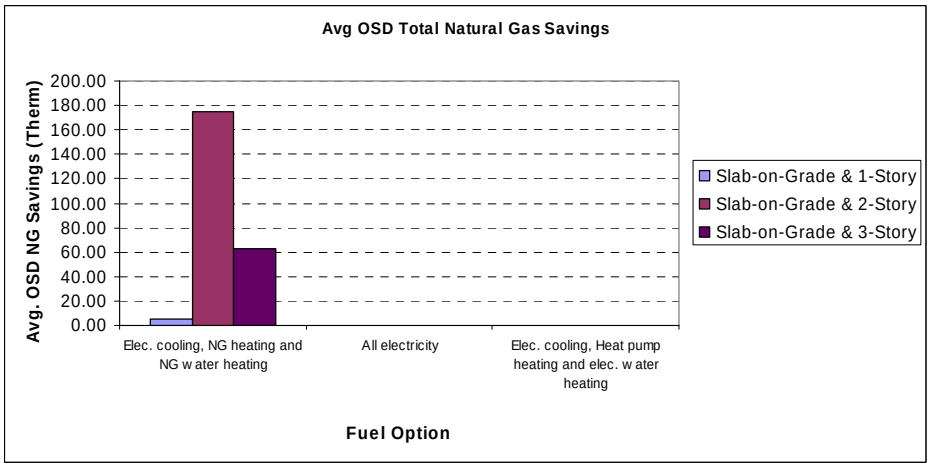

Figure 14: OSD gas savings from multifamily new construction (Harris County).

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